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The Design & Construction Of a Recording Rail-Bond Tester

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THE DESIGN AND CONSTRUCTION OF A RECORDING RAIL-BOND TESTER

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

WILLIAM ARTHUR BUTLER and CARL HENRY HOGE

ENTITLED THE DESIGN AND CONSTRUCTION OF A RECORDING RAIL-BOND TESTER

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Railway Electrical Engineering

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I N D E X

THE DESIGN AND CONSTRUCTION OF AN AUTOGRAPHIC BOND TESTER

Object:- The object of this thesis is to devise a method of testing electric rail bonds which, adopted to use on the University of Illinois test car, will give an accurate record of the high resistance bonds in the track passed over.

History:- The rapid development of electric traction in this country has led to a more thorough study of the principles underlying the construction of the road. The problems dealing with the mechanical structure of the roadbed and with the shape, size, and weight of rails, etc., concern the civil engineer. The electrical engineer is more concerned with the details relating to the electrical circuits of the system.

Careful investigation and experience have, to a large extent, developed several good types of over-head construction, but the rail return circuit has been to some extent neglected. Conservative estimates have placed the losses of power due to poor bonding to be equal to half the total cost of the coal used, to say nothing of damage by electrolysis from leakage currents. These losses are difficult to detect and have been, heretofore, overlooked. A realization of the importance of good bonding has brought forth many individual types of rail bonds.

When it becomes necessary to bond a rail to its full current carrying capacity, welded joints, in general, give the greatest satisfaction. The three methods of welding are cast, thermit, and electric welding.

Cast welding is secured by pouring the metal in a mould surrounding the rail joint prepared for the weld.

Thermit welding is obtained in a somewhat like manner. Here a small amount of finely divided aluminum and iron oxide form a liquid steel by rapid combustion and fusing, immediately over the prepared rail ends.

Electric welding consists in fusing the ends of the two rails together by electricity. Another method of electric welding is to weld a steel strap to each rail, the joint not being continuous between the strap and the rail, but maintained at one or two points of contact.

The above joints have no expansion, are somewhat liable to crack, and are best suited for use in city streets where the track is held rigidly in place by the pavement. As interurban rail installation provides no method for holding the welded rail in alignment except by means of spikes, the above methods of bonding cannot be used. Hence it is only necessary to consider such systems of bonding as will allow the free expansion and contraction of the track.

One of the usual methods of connecting rails electrically is to drill one or more holes about six inches from the end of each rail and insert the terminal of a copper bond, leading across the joint. This terminal is expanded into the hold by various mechanical means, either by driving a steel wedge, or ball, or conical plug, or by expanding the solid copper lug with a screw or hydraulic pressure. The different coefficients of expansion of steel and copper

through the variations of temperature soon cause a decrease in the diameter of the hole and an increase in its length. This permits moisture to enter which will oxidize the contact surfaces. As the temperature rises the copper plug in the steel plate must expand at a greater rate than the steel. The force of the copper's expansion is not great enough to increase the diamter of the hole in the steel, hence its entire expansion takes place in a line parallel with the axis of the hole. Now, as the joint cools, there is nothing to prevent the copper from contracting in all directions. The plug is, therefore, of less diameter and greater length than before heated.

Expanded terminal bonds comprise all those which depend upon expanding a soft copper core into contact with the rail through a hole in the web or flange.

Soldered bonds consist of a laminated copper conductor ending in two solid heads. These heads are joined to the rail by soldering, welding, or brazing. The bond is attached to the outside of the ball of the rail, to the web of the rail under the fishplates or to the bottom flange of the rail underneath the joint. In two of these cases the bond is open to view, which greatly facilitates inspection and renewal but which also makes it liable to theft--- a great disadvantage. It is very difficult to obtain a contact by soldering which will stand the vibration and shocks to which the joint is subjected, but the welded and brazed bonds appear to be more free from this objection.

These types of bonds give good service for a comparatively short time as their life is very uncertain. Failures are caused by the change in temperature conditions (as explained above) or by the vibration or shifting of the track due to passing cars. These failures are liable to occur at any time. Hence, after a short length of time, the rail return circuit will begin to increase in resistance, and in order to keep this within the proper limits a rigid inspection and frequent bond renewals are required.

A realization of the loss of power due to bad bonding and of the damage to water and gas mains from electrolysis, due to leakage currents, has caused the many companies to investigate methods of bond testing. One method, simple in theory but slow in operation, is to find the voltage drop over the bond and solid rail by means of a milli-voltmeter. This method, it will be seen, is very tedious and inaccurate as the value of the current in the rail is not a constant.

A knowledge of the difficulties of testing bonds accurately and speedily has led the authors to undertake this problem as a thesis subject. The problem, as it is presented to us, is the determining, marking,and recording of defective bonds during a trip over a section of track at moderate speeds. Many possible solutions of the problem present themselves but after careful investigation it was not thought practicable to consider methods which rely upon rail currents for their effective operation. This calls

for an external source of current and some way of determining the difference in the condition of the solid rail and the bonded joint. One method, which presented itself favorably, was the use of a milli-voltmeter with relay connections so that when the reading exceeded a certain predetermined limit, caused by a high resistance joint, the record would be made by an offset upon the chart. This seemed a fairly good method but upon consideration it was seen that no allowance could be made for currents in the rails and no value could be placed upon the resistance of the joint as this depended upon the total current flowing at the given time.

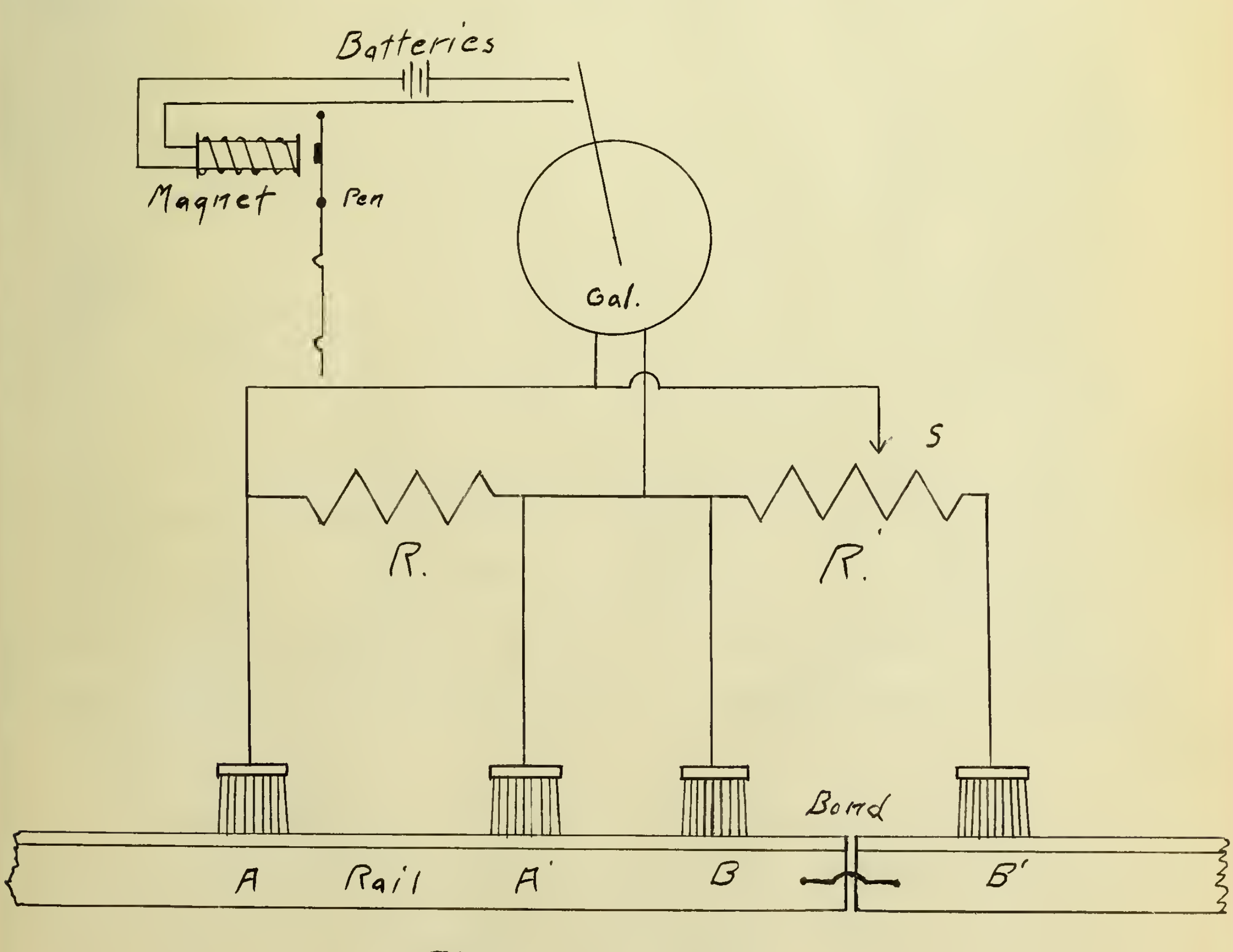


Figure 2.

Another method and the one finally adopted consists of the balancing of resistance due to the solid rail with an equal length of track containing the joint, the balance being obtained by the use of a galvanometer and two equal resistances as shown in Fig. 3. The current through the auxillary resistances R and R' will be proportional to the resistance of the separate sections of the track between the brushes, and if equal, the resistance of the bond will be zero. Due to the connections of the galvanometer as shown in the Fig. 3, the voltages of the two resistances are opposed and thus with equal conditions, no movement of the galvanometer needle can take place. The sliding contact S permits of movement so that any portion of the voltage of R' can be opposed to that of R, thus offering a means of comparison. For example, with S at the center of R', a balance would be obtained when the resistance of the rail joint equalled the resistance of that section of the rail between the brushes A and A'. Again, with S at the quarter point, the resistance of the joint would be equal to the resistance of three times the length of track between the brushes A and A'. With the length between the brushes constant, the movement can be made to give readings in feet of rail. This is the usual method of designating bond resistance.

The galvanometer needle is so arranged as to close the circuit through an electric magnet, whenever it is deflected by a high resistance bond. This magnet makes an offset on

the test car chart, whenever the circuit is closed. From the fact that the apparatus is arranged for it, any equivalent feet of rail resistance, within reasonable limits, may be assumed as a good bond. This allows the relative condition of all parts of the track to be recorded on the chart. As the position of the car is definitely known, it is a simple matter to find and mark the bonds that need to be repaired.

The bond marking device consists of an air-tight tank connected to the air reservoir through a magnetic valve. The valve, being connected in series with the recording apparatus, is actuated simultaneously with the recording device. The opening of the valve allows air under pressure to enter the white-wash tank, thus ejecting a small quantity of the white-wash on the track.

Construction:- The source of current is a motor generator set, placed on the car floor as shown in the photograph, Fig. 4. The two machines are connected by a belt and controlled by means of a switch and starting box arranged on the side of the car.

The motor was manufactured by the Barriett Manufacturing Company of Cincinnati, Ohio. It operates on 500 volts at 1700 R. P. M., and is rated at 4 Horse Power, the current 6.4 amperes.

The generator was manufactured by the Eddy Electric Manufacturing Company of Windsor, Connecticut. It is driven at 1900 R. P. M., and will supply about 200 amperes

at 12 volts, being a standard electro-plating generator.

The current brushes, as shown in photograph, Fig. 5, were constructed by filling the head of a steel roughing brush with babbit metal and imbedding a copper lead in the metal. This insures good electrical contact through all the bristles to the rail. In order to insulate the brushes from the truck a wooden block was fastened over the babbit metal and to this the brush hanger was fastened. The brushes were fastened to the truck by a steel strap as shown in photograph, Fig. 6. The slotted strap was bolted to the truck with cap screws which allowed an adjustment of the pressure on the rail.

The voltage brushes were first fastened to the truck and allowed to rub against the wheels as shown in photograph, Fig. 6. But on account of interfering currents from the motor and paralleling wheel circuits this did not give the desired results,-- the offsets on the chart were very erratic due to the variation of the resistance of the car trucks. The brushes were then arranged to rub on the rail as shown in photographs, Fig. 7 and 8.

In place of the adjustable resistances and galvanometer as shown in the schematic diagram, a Whitney direct reading bond tester was substituted as it operates on the same underlying principles. Contact was made for the recording apparatus by allowing the needle to swing against a silver contact, thus completing the circuit through a relay, the relay being necessary as the needle contact would not carry

sufficient current to operate the recording magnet.

The wiring circuits for the voltage and current brushes were placed under the car body and were led to the galvanometer and the generator respectively. The generator leads were of sufficient size to carry approximately 200 amperes.

Experiments:- After testing all the circuits and adjusting the brushes, a trip was made with the voltage brushes on the wheels as shown in Fig. 6. While in the car barn the apparatus seemed to work and give good results, but upon trying it in actual test on the Illinois Traction System with current through the motors the results were very unsatisfactory. The deflection of the needle was uncertain and it seemed to give different results while the car was accelerating than when coasting. The voltage brushes were shifted so as to make contact directly with the rail, as shown by photograph, Fig. 7 and 8.

In looking over the results of the first test and trying to determine the cause of the failure, it was noticed that several factors were present that could have been responsible for the errors. In the first place, the voltage drop was taken between the two wheels as they are more or less electrically inter-connected by the truck body. This connection is through a film of oil-- around the axle-- and by a parallel circuit through the other pair of wheels. It will be seen that this connection would vary greatly at the best and this would account for the erratic action of the needle. Moreover, there would be a short circuiting effect

and this would greatly interfere with the good operation of the apparatus.

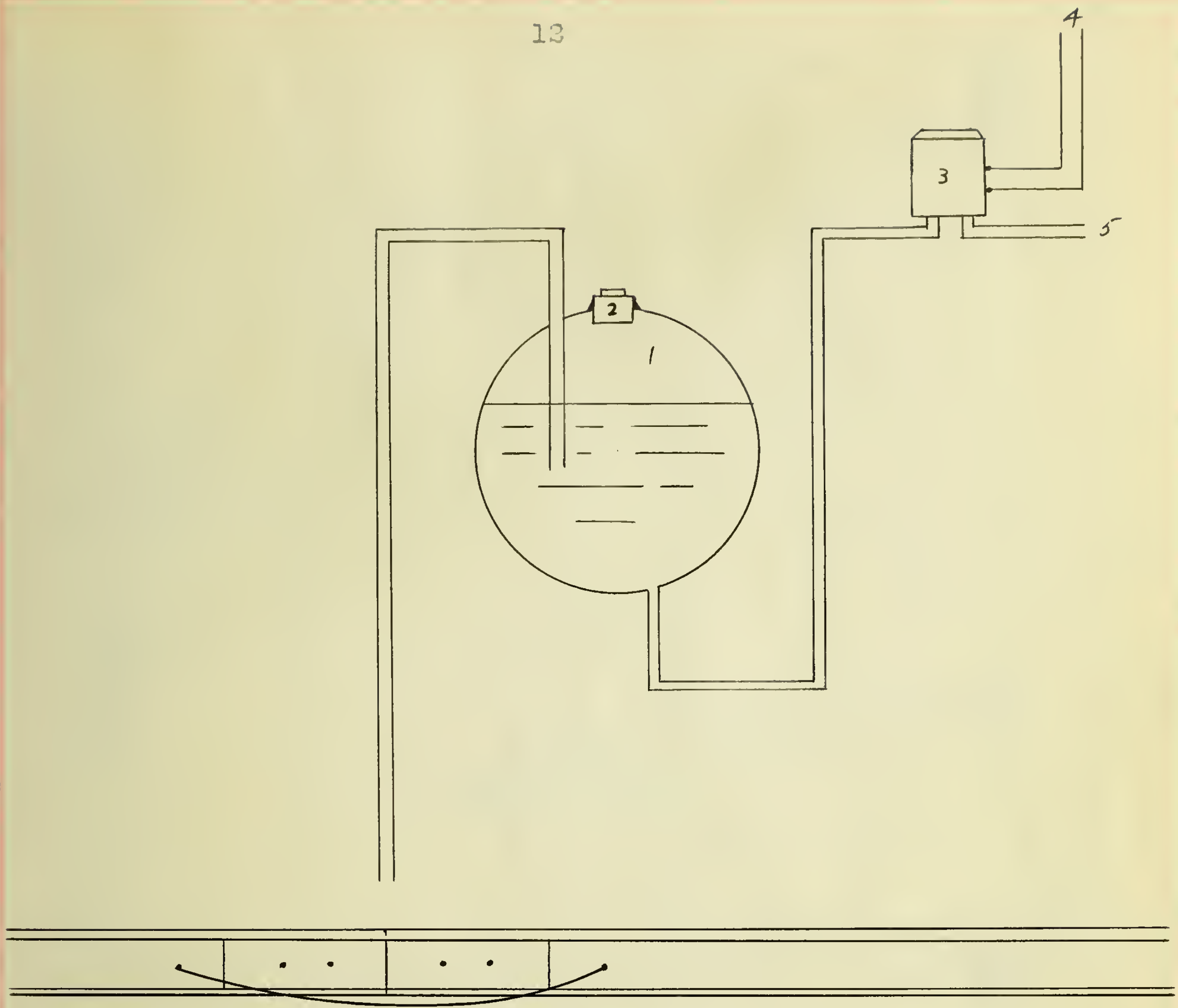
Tests were made with the voltage brushes, as altered, and the results were satisfactory. The change had overcome the erratic action of the galvanometer and the poor bonds were easily detected. The car was first run out on the track and stopped with one pair of wheels directly over a rail joint, and while in this position, the galvanometer deflected in one direction. Upon moving the car forward until the other pair of brushes were over the bond, a deflection was noticed in the other direction. The resistance was changed while in this position and the needle came back to the center with the dial indicating six feet of rail resistance, i.e., the resistance of that particular bond was equal to the resistance of approximately six feet of rail. Next, the car was run up and down a portion of the track and at two separate places the deflection indicated a bond of high resistance on every trip made. This was sufficient proof that the apparatus was in good working condition.

While the results of the above experiments were satisfactory on the whole, there is still room for improvement in the brush design. Both the current and voltage brushes, Fig. 7 on that end of the truck operated well. It was the voltage brushes upon the other end of the truck that still gave trouble. They had a tendency to slip off the track and were not a complete success,-- but this is only a minor detail of the design that could be remedied easily.

Conclusions:- In reviewing the results obtained by tests, the main features of the design, as indicated, do not differ materially from the original plan. The recording part of the apparatus, together with the bond marking device, gave good results. On a chart taken during a trip over any section of tho track the record of the defective bonds was made by offsets from the datum line. This, together with the distance and other reference curves, gave sufficient record of the track condition. As the recording magnet and bond marking device are in the same circuit, each poor bond was marked, when passed over, by a small quantity of white-wash ejected on the road bed. This took place simultaneously with the operation of the recording pen.

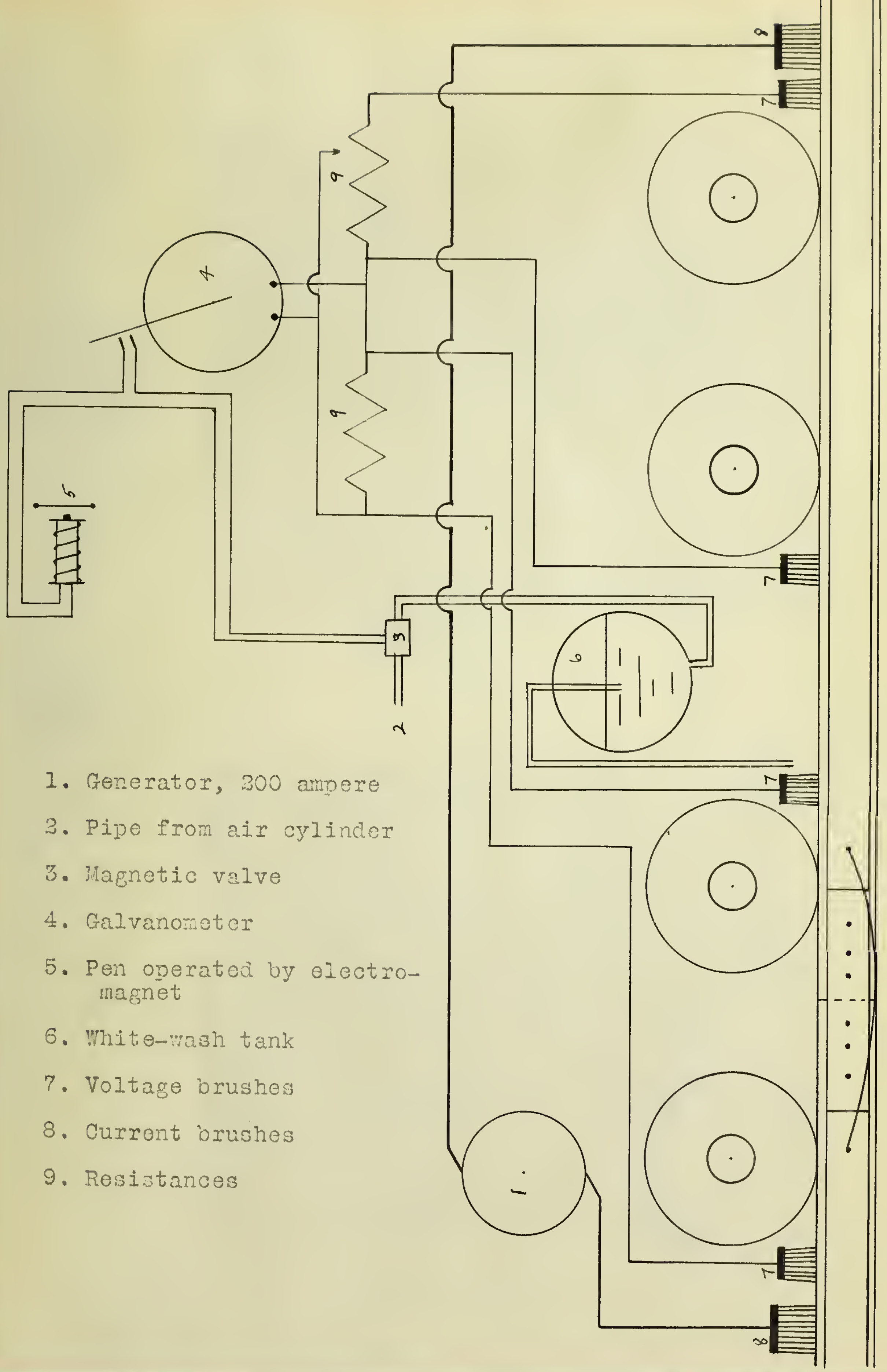
As stated above, the voltage brushes were not a complete success, and it would seem as if a brush designed similar to the present current brushes would give more satisfactory results. This, in brief, seems about the only change necessary for entirely satisfactory operation.

In conclusion, it seems possible that the system outlined in this thesis could be adopted to practicable use with satisfactory results. The rapidity with which the test can be made and its fair degree of accuracy would warrant, in most cases, the outlay necessary for the construction of the apparatus.



MARKING DEVICE.

1. White wash tank
2. Plug
3. Magnet valve
4. Leads from relay
5. Pipe from air tank



1. Generator, 300 ampere
2. Pipe from air cylinder
3. Magnetic valve
4. Galvanometer
5. Pen operated by electro-magnet
6. White-wash tank
7. Voltage brushes
8. Current brushes
9. Resistances

Schematic Diagram of Autographic Bond Tester.

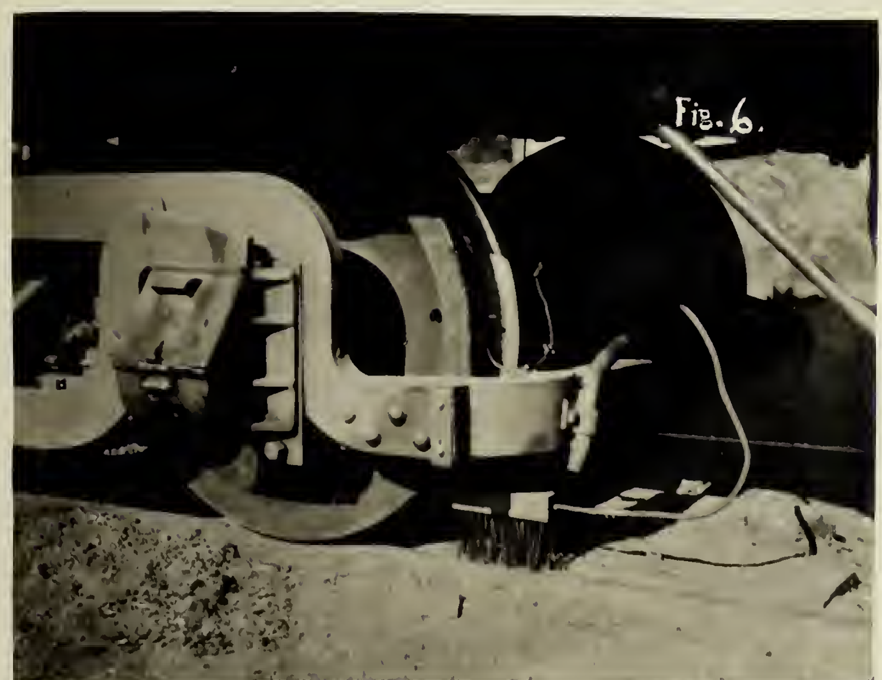
Fig. 3.

TEST CAR

Fig. 4.

MOTOR GENERATOR SET

CURRENT BRUSHES



CURRENT AND VOLTAGE BRUSHES

CURRENT AND VOLTAGE BRUSHES

VOLTAGE BRUSH